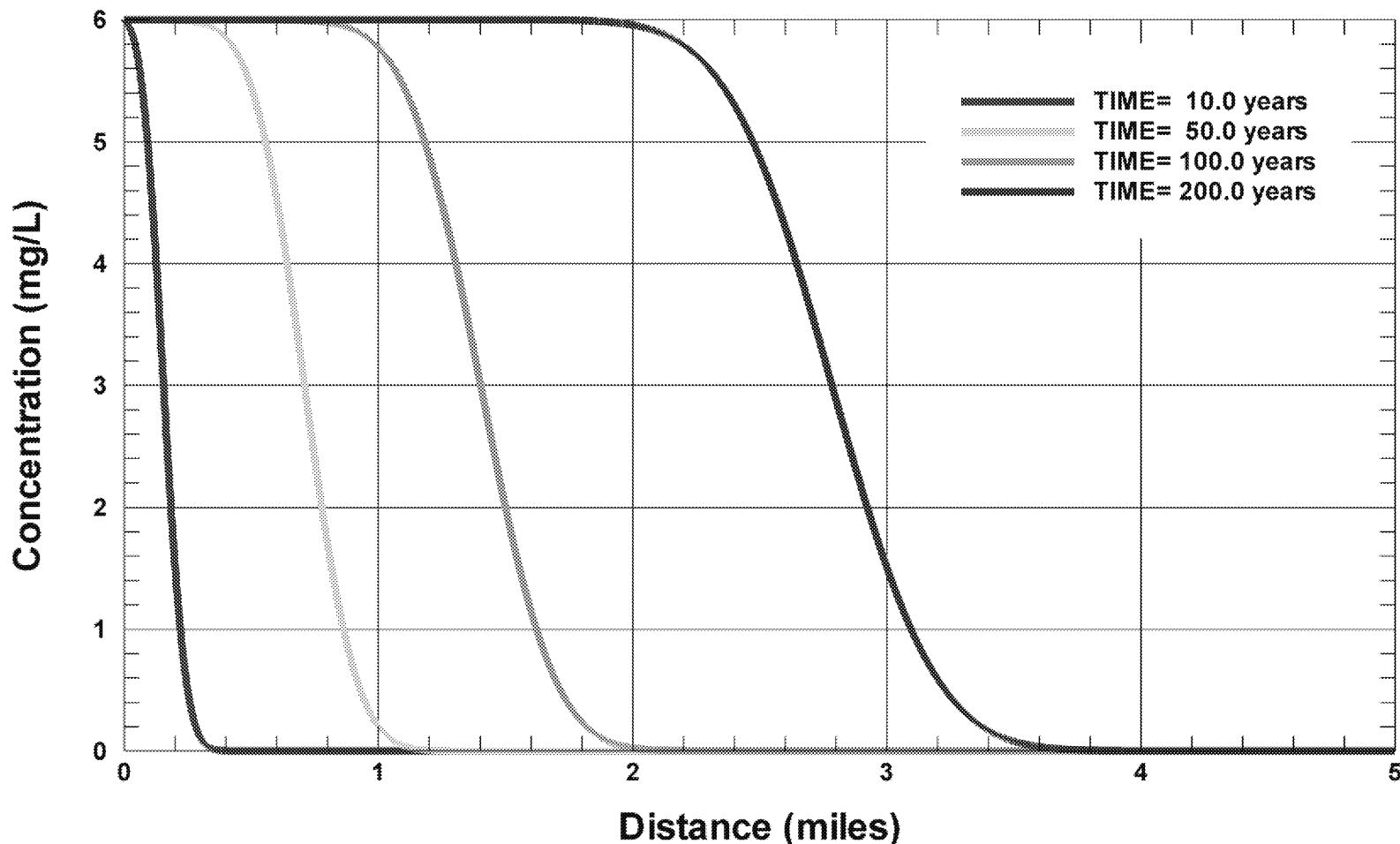
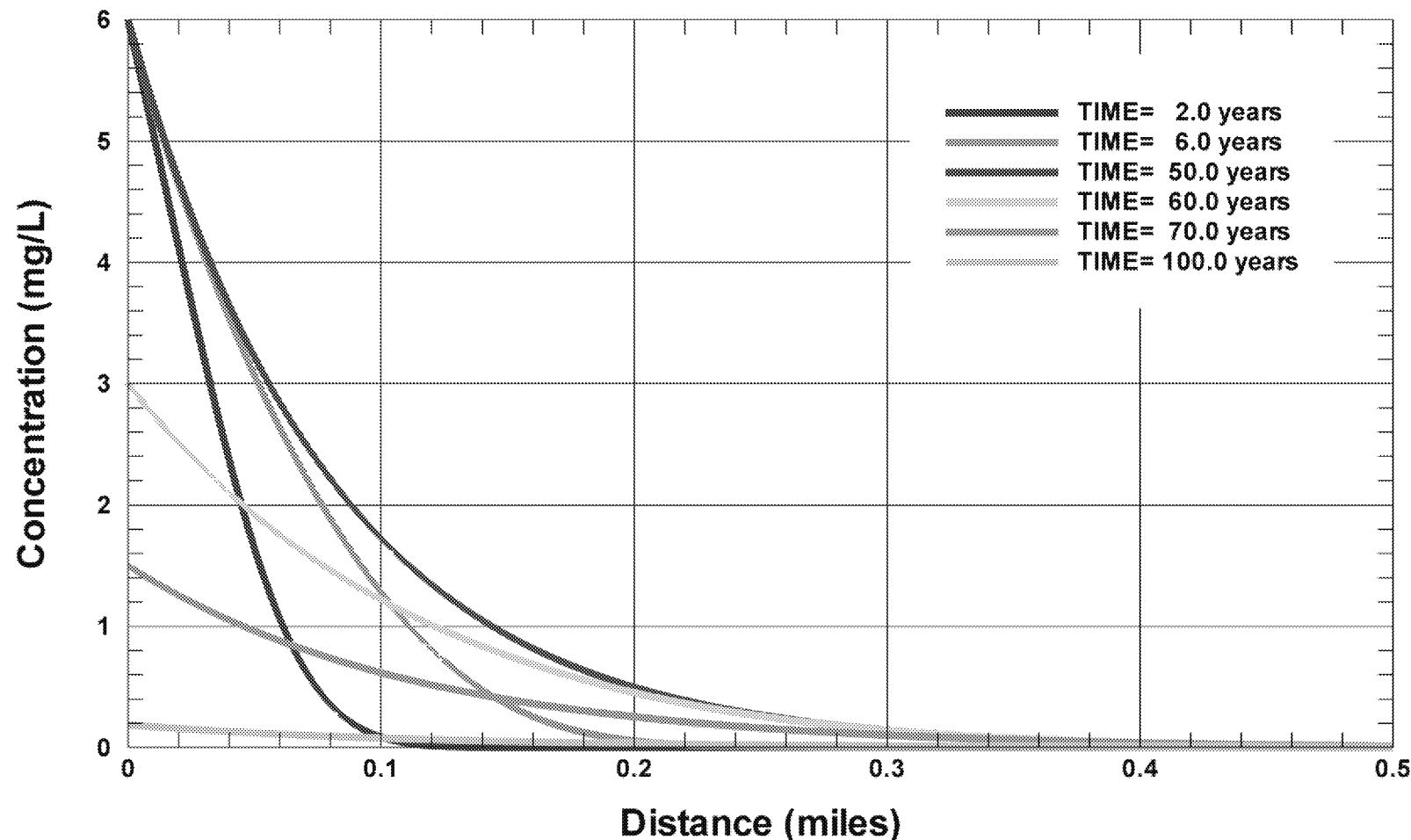


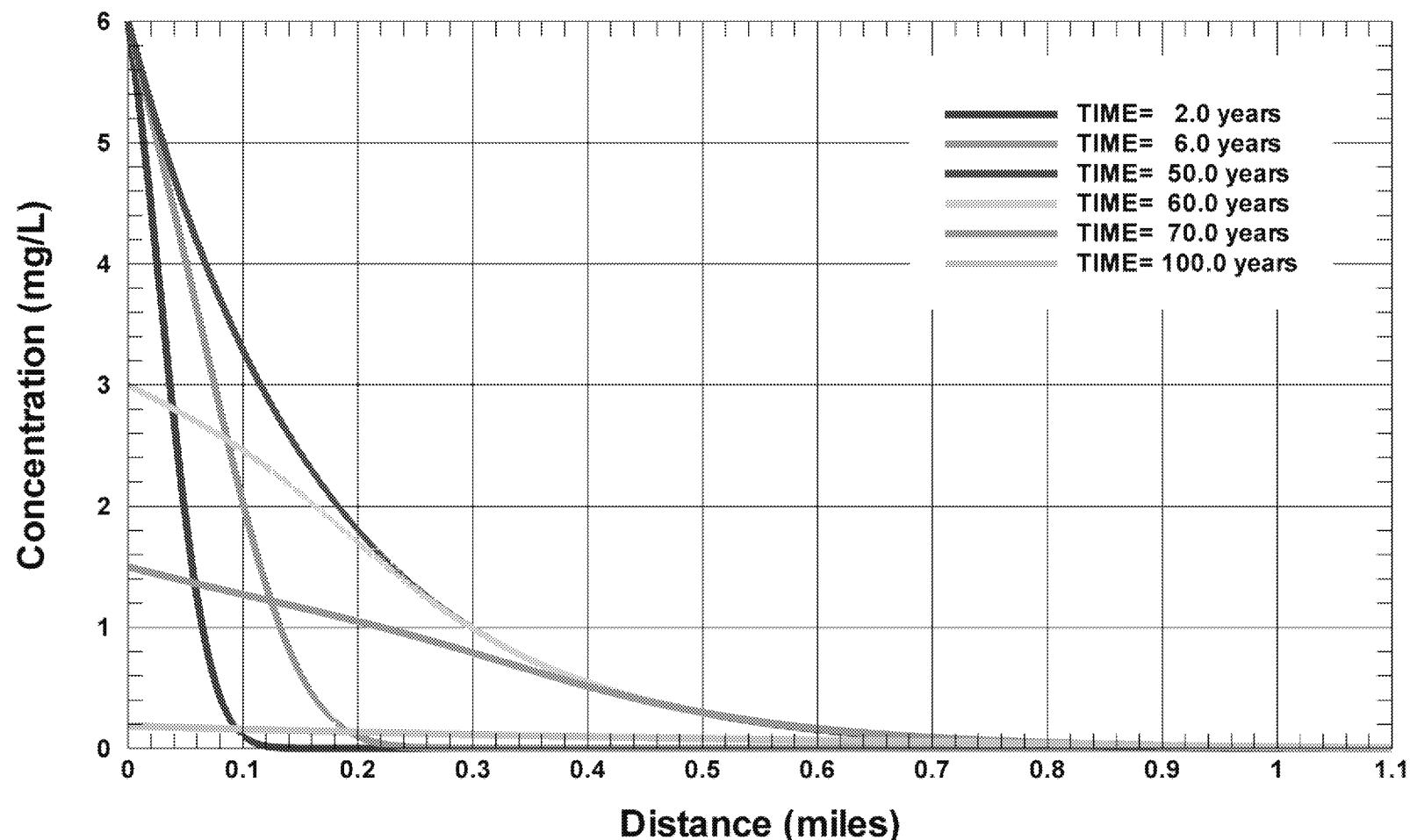
**Figure 1**  
**Benzene Plume Centerline Concentration in UWBZ**  
**No Biodegradation**



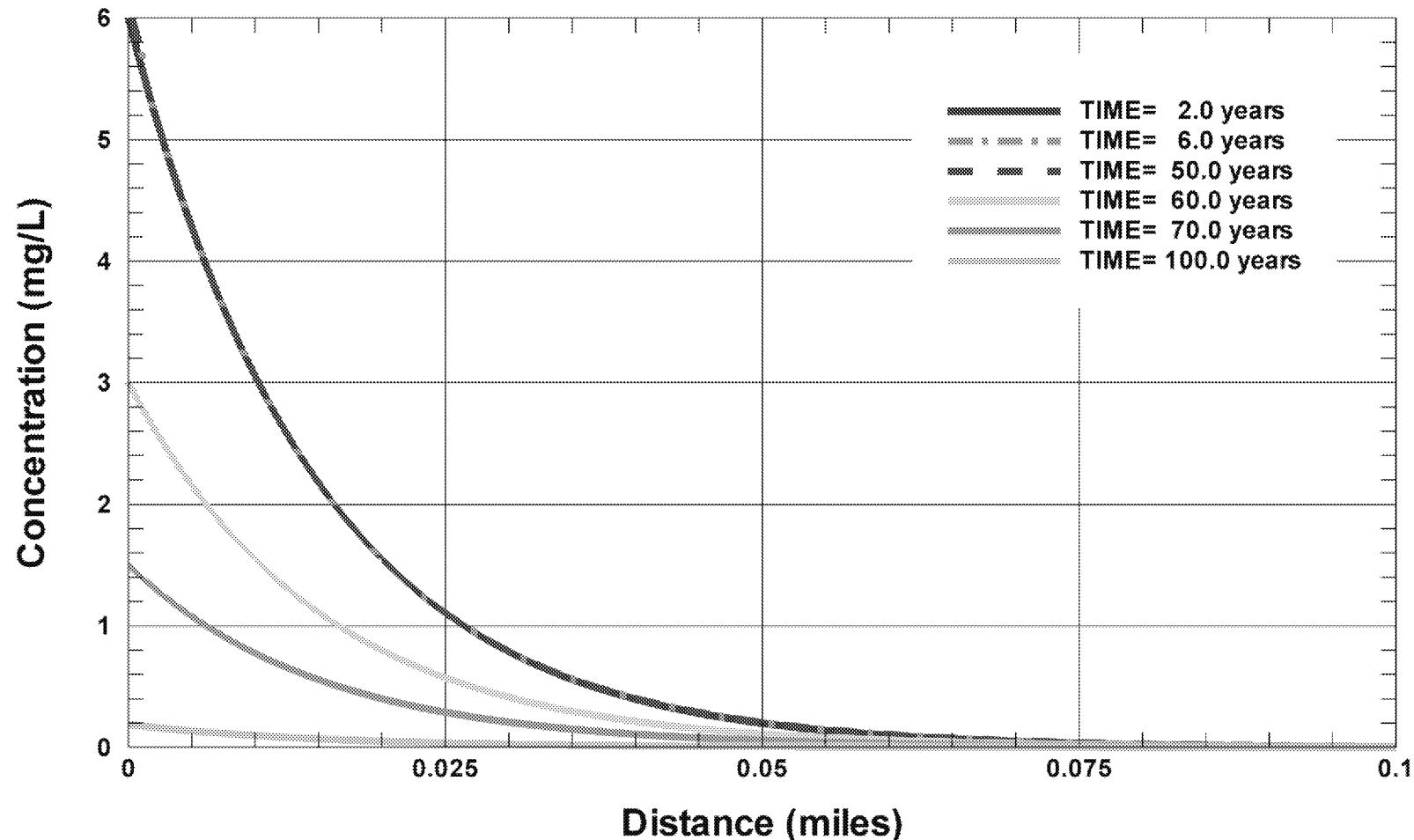
**Figure 2**  
**Benzene Plume Centerline Concentration in UWBZ**  
**790-Day Biodegradation Half-Life (Bo's Memorandum Table 10 Utilization Rate)**  
**50-yr Pre-EBR Constant Source**  
**100-yr Source Remediation using EBR**



**Figure 3**  
**Benzene Plume Centerline Concentration in UWBZ**  
**5-yr ("Slow") Biodegradation Half-Life**  
**50-yr Pre-EBR Constant Source**  
**100-yr Source Remediation using EBR**



**Figure 4**  
**Benzene Plume Centerline Concentration in UWBZ**  
**80-Day ("Fast") Biodegradation Half-Life (Bo's Memo Table 11 Utilization Rate)**  
**50-yr Pre-EBR Constant Source**  
**100-yr Source Remediation using EBR**



## **Appendix A**

### **Analytical Solution**

## Combine Solutions C13 & C5

C13. Governing Equation  $R \frac{\partial c}{\partial t} = D \frac{\partial^2 c}{\partial x^2} - v \frac{\partial c}{\partial x} - \mu c + \gamma$

Initial and Boundary Conditions

$$c(x, 0) = C_1 = 0$$

$$c(0, t) = \begin{cases} C_0 \\ C_a + C_b e^{-\lambda t} \end{cases} \quad \begin{cases} 0 \leq t \leq t_0 \\ t > t_0 \end{cases}$$

$$\frac{\partial c}{\partial x}(0, t) = 0$$

$$+ C_0 \cdot \delta(x, t)$$

Analytical Solution [see Cleary and Ungs (1974) and Marino (1974b) for some special cases]

$$c(x, t) = \frac{x}{\mu} + \left( C_1 - \frac{x}{\mu} \right) A(x, t) + \left( C_a - \frac{x}{\mu} \right) B(x, t) + C_b E(x, t) \quad \begin{cases} t > t_0 \\ 0 \leq t \leq t_0 \end{cases}$$

$$\text{where } = C_0 \cdot B(x, t) \quad 0 \leq t \leq t_0$$

$$A(x, t) = \exp(\mu t/R) \left\{ 1 - \frac{1}{2} \operatorname{erfc} \left[ \frac{Rx - vt}{2(DRt)^{1/2}} \right] - \frac{1}{2} \exp(vx/D) \operatorname{erfc} \left[ \frac{Rx + vt}{2(DRt)^{1/2}} \right] \right\}$$

$$B(x, t) = \frac{1}{2} \exp\left(-\frac{(v-u)x}{2D}\right) \operatorname{erfc} \left[ \frac{Rx - ut}{2(DRt)^{1/2}} \right]$$

$$+ \frac{1}{2} \exp\left(-\frac{(v+u)x}{2D}\right) \operatorname{erfc} \left[ \frac{Rx + ut}{2(DRt)^{1/2}} \right]$$

$$E(x, t) = e^{-\lambda t} \left\{ \frac{1}{2} \exp\left(-\frac{(v-w)x}{2D}\right) \operatorname{erfc} \left[ \frac{Rx - wt}{2(DRt)^{1/2}} \right] + \frac{1}{2} \exp\left(-\frac{(v+w)x}{2D}\right) \operatorname{erfc} \left[ \frac{Rx + wt}{2(DRt)^{1/2}} \right] \right\}$$

$$+ \frac{1}{2} \exp\left(-\frac{(v+w)x}{2D}\right) \operatorname{erfc} \left[ \frac{Rx + vt}{2(DRt)^{1/2}} \right]$$

Summary

and with

$$c(x, t) = C_0 \cdot B(x, t) - C_0 \cdot B(x, t-t_0) + C_b \cdot E(x, t-t_0)$$

$$= C_0 \cdot B(x, t)$$

$t > t_0$

$0 \leq t \leq t_0$